islands need not have been stable. This aspect of the coral-reef problem is examined in an essay submitted to the Geological Society of America for publication in its Bulletin.

The foregoing discussion will be presented in greater detail in the Annals of the Association of American Geographers.

[1] J. Macgillivray, *Narrative of the Voyage of H. M. S. Rattlesnake*, London, 1852. 2 vols. See i, 182; ii, 72.

[2] B. H. Thomson, "New Guinea: Narrative of an Exploring Expedition to the Louisiade and D'Entrecasteaux Islands, "*Proc. Roy. Geogr. Soc.*, **11**, 1889 (525–542).

[3] A. G. Maitland, "Geological Observations in British New Guinea," *Queensland Geol. Surv. Pub.*, **85**, 1892. "Salient Geological Features of New Guinea," *Journ. W. Austral. N. H. Soc.*, **2**, 1905 (32–56).

[4] "Problems Associated with the Study of Coral Reef," *Sci. Monthly*, **2**, 1916 (565).

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*EXPERIMENTS WITH THE VACUUM GRAVITATION NEEDLE**

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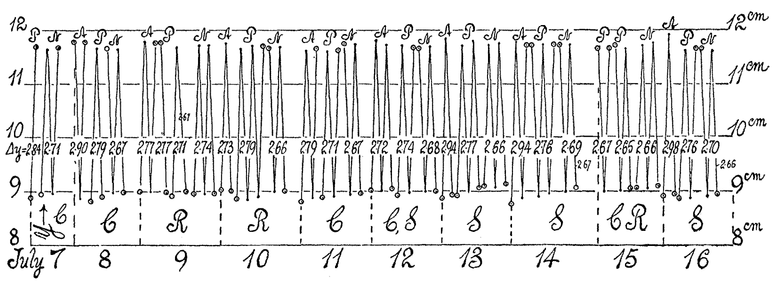
1. *Apparatus.*—At the end of the previous summer's experiments, a form of apparatus was installed capable of exhaustion and containing a gravitation needle made of wires as thin as possible (bronze, .24 mm. in diameter) compatibly with the lead weights, m, at the ends. The object of this was to diminish the radiation effect to an inferior limit, always remembering that the lateral area of the shots m is necessarily in presence. The narrow case was a rectangle of brass with reentrant sides, into which plates of thick glass could be sealed with cement free from air leakage.



Each attracting weight M had a mounting quite independent of the case and could easily be moved between stops from one side to the other of it by a crank-like arrangement.

The half silver method of reading the deflections of the needle and other details were retained, with the scale distance, $L = 447.5$ cm.

The masses of the attracted lead balls at the end of the filamentary needle were $m = .6295$ grams each, though the quartz fibre would have been strong enough to hold a larger mass to advantage. The distances R of the

center of the mass M from the center of the shot m were obtained by calipering.

The moment of inertia of the needle $2l = 22.0$ cm. long between centers of $m = .6295$ g has for its main part $2ml^2 = 152.5$. To this is to be added the moment of inertia of the stem wire ($\rho = .0044$ grams per cm.), 3.9; of the oblique wire brace or tie, 1.0; and of the glass filament added for ridgity, 2.0; making a total of $N = 159.4 = ml^2(1+s) = 152.5(1+.0452)$.

The torsion coefficient of the wire was found from the period T_1 of the needle vibrating in vacuo, by a stop watch. As T is over 5 minutes, it is necessary that the arc of vibration be relatively large; otherwise the passage through equilibrium is too slow. Periods were found as follows: $T_1 = 311.5$, 310.0, 312.0, 311.5, 311.0, 311.2; Mean $T_1 = 311.2 \pm .28$ sec. The discrepancies result from the presence of radiation forces.

The logarithmic decrement, λ, obtained from observations of consecutive elongations showed $\epsilon^\lambda = 1.35$ in the first and 1.34 in the (better) second series, which makes $\lambda = .293$ nearly. Hence the true period T of the needle is

$$T = T_1/\sqrt{1+\lambda^2/4\pi^2} = T_1/1.0011.$$

The intervals on the stop watch moreover were corrected (on comparison with a chronometer) by the factor 1.0055. This with the preceding equation gives

$$T = T_1(1.0012) = 312.6 \text{ sec.}$$

2. *Equations.*—The approximate equation for the gravitation constant γ, containing all quantities to be measured when the needle of semi-length l is used to find the torsion coefficient of the quartz fibre, is

$$\gamma' = (\pi^2 NR^2/LT^2 lMm)\,\Delta y \tag{1}$$

Δy being the ultimate double amplitude for the scale distance L, when the attracting weight M passes from side to side of m.

Since the stem is also appreciably attracted, a correction must be made for it. If t/τ is the ratio of torques for stem and mass m separately

$$t/\tau = (\rho R/lm)(\sqrt{R^2+l^2} - R) \tag{2}$$

when ρ is the mass per cm. of the stem.

Hence finally the corrected constant is

$$\gamma = \gamma'/(1+t/\tau). \tag{3}$$

For the case of two attracting masses M' and M'', one at each end of the needle and coöperating, we should have

$\gamma = K'\Delta y' = K''\Delta y'' = (\Delta y' + \Delta y'')/(1/K' + 1/K'')$; and $\Delta y = \Delta y' + \Delta y''$, whence

$$\gamma = \Delta y/(1/K' + 1/K'') \tag{4}$$

K' and K'', the corrected coefficients, are usually not very different in value.

If in equation (1) we replace N by $2ml^2(1+s)$ where $s = .0453$, m vanishes from the equation (except in the corrections) which now takes the simpler form

(5) $$\gamma = 2\pi l R^2(1 + s - t/\tau)\,\Delta y/LMT^2$$

showing that l virtually enters in the first power only.

3. *Observations.—Large attracting masses M coöperating.* The constants entering equation (1) have been given for the needle. The new data are

$$M = 3368 \text{ grams} \qquad R = 5.67 \text{ cm.}$$

Hence the following relations result:

$$\gamma' = 10^{-8} \times 4.960\,\Delta y'; \text{ and } t/\tau = .0241,$$

which in equation (3) gives

$$\gamma = 10^{-8} \times 4.844\ \Delta y'.$$

The second mass was a little smaller; viz., $M'' = 2947$ grams and $R = 5.43$ cm.

Hence the approximate value of K'' is $10^{-8} \times 5.198$. The value of t/τ is .0236 so that in view of the factor 1/1.0236

$$\gamma = K''\,\Delta y'' = 10^{-8} \times 5.078\,\Delta y''.$$

If the balls, M, act together

$$\gamma = \Delta y(1/K' + 1/K'') = 10^{-8} \times 2.479\,\Delta y$$

which is partically the fourth part of $K' + K''$. The normal deflection should be $\gamma/K = 2.69$ cm.

The observations, begun on July 7 and continued for some time, 3 times daily, forenoon (A), afternoon (P) and night (N), with periods of from 30 minutes to one hour between consecutive observations,† are given in the figure, the mean value of Δy being inscribed on each group of observations terminating in little circles. As the normal value should be $\Delta y = 2.69$ cm., it is obvious that only the night (N) observations are acceptable. On July 7 the apparatus, which had just been set up, was slowly approaching thermal equilibrium.

If we exclude the first night datum as the apparatus was too fresh and the exceptional datum during the fog of July 9, and take the last doublets specified, the mean of the eight deflections is $\Delta y = 2.666 \pm .0017$ cm. Therefore

$$\gamma = 10^{-8} \times 2.479\,\Delta y = 10^{-8} \times 6.609$$

with a mean error in T and Δy together, of less than .3%. This is as near the normal value as one may hope to get, seeing that the small individual deflections, Δy, must be read off on a millimeter scale. If all night observations were taken $\gamma = 6.63$ would result.

Night observations made on an exhausted gravitational apparatus, therefore, give promise of trustworthy results, particularly if a season of uniform temperature is chosen and a relatively finer quartz fibre is inserted. While the exhaustion here in question has not been carried further than a few millimeters, the experiments are all aiming at the final test under complete exhaustion.

* Advance note from a report to the Carnegie Institution of Washington.

† To secure better vision the scale was slightly shifted on July 13.